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A CRITICAL REVIEW OF THE LITERATURE OF 1958 ON WATER POLLUTION

H. F. Clark, et al

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

March 1959

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A Critical Review of the *Literature of 1958 on Water Pollution*

Prepared for the Research Committee
of the
FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

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BIOLOGY

Pollution Surveys and Investigations

Studies on the effects of the sewage effluent from the Maple Lodge Works, an activated sludge system treating wastes from 200 to 260 thousand people in the Colne River Valley, indicated that there was an apparently flourishing population of warm water fishes living in the undiluted sewage effluent. The abundance of fish varied greatly, with populations being highest in summer and lowest in winter. Fish died when the D.O. content of the effluent was below 30 percent of saturation. In two and a half years 10 fish kills were reported. No mortality was attributed to concentrations of ammonia, detergents, or metals present in the sewage effluent (177). In the Vistula River pharmaceutical and tannery wastes caused a very marked reduction in the variety of aquatic organisms in the vicinity of the outfall (233).

Qualitative and quantitative analyses of the aquatic biota were made in connection with pollution surveys of the Laramie and Shoshone Rivers. The fisheries of 46 miles of the Shoshone have been seriously impaired by a variety of pollutants which are listed under five headings. Fish production in the Laramie is also affected by a number of factors, including irrigation diversions (33). An investigation of the effects of wastes discharged into

a bay in Japan indicated that phenol was manifest in the upper layers of sea water in an area having a radius of 0.5 km from the outfall. Contamination of the bottom by iron to the extent of 6 percent covers an area of 0.5 sq km (210). It has been found that diving with the use of SCUBA equipment is helpful in evaluating the effects of the discharge of wastes into the sea. Observations can be made on: flow patterns from outfalls, effects on aquatic populations, and other pollution parameters (145).

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Fish Kills

Acid waters from an operating coal mine killed fish in 16.3 miles of Goose Creek, a tributary of the South Fork of the Kentucky River. Twenty

days after the kill, fish population studies indicated 61.3 lbs. of fish per acre above the mine outfall and 5.4 lbs. per acre below the outfall. The fish killed were valued at $13,325.00. Pan fish comprised the largest group in the kill (220). It has been found that wastes from the manufacture of superphosphates and other chemicals which may be nontoxic in sea water at normal pH levels become toxic when the pH is lowered. A large kill of fish in the San Francisco Bay in 1957 is attributed to the action of a combination of factors (6). French authorities determined that a U. S. Army Quartermaster laundry was responsible for several fish kills in the stream receiving the laundry wastes (104).

Water Quality Criteria for Aquatic Life

General

The water quality of the Columbia River has been significantly changed in the past 45 years due to the construction of dams. The use of water for agricultural, industrial, and domestic purposes has increased. Water returned from these uses differs in quality from the original stream water. Water temperatures in the Central Columbia, the lower Snake, and in the Yakima are now quite high in summer and dissolved solids are considerably higher (211). Return irrigation water contains more dissolved solids and is generally warmer than the original stream water. Water used for irrigation should not have over 1-2 ppm of Boron and the content of sodium, bicarbonate, and other materials which affect plant growth should be low (226).

Antagonistic relationships between manganese and iron, and between calcium and manganese in relation to algae growth have been demonstrated. The manganese content of lake waters appears to reach levels high enough

to be toxic to algae were it not for this antagonistic action of calcium (95). The relative requirements and availability of nitrogen and phosphorus for growth of Microcystis aeruginosa in southern Wisconsin lakes was also evaluated. It was demonstrated that nitrogen content is often close to the limiting amount and that nitrogen is present in far less abundant supply relative to need than is phosphorus. The practical implication of these results is the possible control of blooms by the removal of nitrogen or other limiting nutrients (96).

Suspended Solids and Turbidity

Concentrations of certain suspended materials as high as 1458 ppm were filtered and passed through the gut of Daphnia magna with no apparent harm while others were toxic at much lower levels. Charcoal and montmorillonite were toxic at 100 ppm; ground glass at 98 ppm; chlorite at 120 ppm; and illite at 264 ppm. Pond sediments were not toxic at any of the tested levels (190).

Temperature

Studies of the effect of temperature on reproduction have indicated that temperature and condition are the controlling factors. At extreme temperatures fish are not ripe at seasons when nearby populations under favorable temperatures are in spawning condition. Light duration and intensity do not appear to affect fecundity of greenthroated darters. For this species optimum temperature for egg production appears to be between 20° and 23° C (120). Temperatures in the main stem of the Columbia River during the period of egg development of the chinook salmon are usually about 57° F. at spawning time, then they drop to 36° F and later increase to about 47° F. Experimental studies with groups of chinook eggs at temperatures averaging 4° F. colder

and 2°, 4°, and 8° F. warmer, indicated that significant mortality above that in the controls occurred only in the warmest lot. The results of these studies indicate that incubation can begin at temperatures as high as 61° F. without significant loss (169).

Rainbow trout held in distribution tanks at 54° F. died when planted in a southeastern Wisconsin lake having a surface water temperature of 74° F. Since this latter temperature is not lethal in nature, it is thought that it was the change in temperature which was lethal to the planted fish. Fish slowly acclimated to the higher temperature, survived (217).

Two groups of goldfish with a mean weight of 14.2 g were subjected to two different photo periods. The first group received 8 hours of illumination and 16 hours of darkness while the second group received 16 hours of illumination and 8 hours of darkness. Both groups were held at the same temperature and received the same intensity of light. The first situation corresponded to sunlight in winter and the second to summer sunlight. When the thermal resistance of the two groups was tested it was found that the first group survived low temperatures best; whereas the second group was the most resistant to high temperatures (115).

The temperature of the cooling water of the Johnsonville, Tennessee, steam plant is raised about 10° F. in winter and 5°-6° F. in April and May. While no significant increase in plankton production was noted due to the warming of the harbor receiving this effluent, some differences in fish population were noted. Threadfin shad were attracted in large numbers and they, in turn, attracted the sauger which feeds on them (72).

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Dissolved Solids

Investigations on the osmoregulation of 3 species of salmonids (Salmo salar, Salmo trutta, and Salmo gairdnerii) demonstrated that the tolerance of these fishes to sea water and their ability to regulate body fluids in water of high salinities depends upon the size of the fish as well as on its age and species (175). The maximum tolerances of selected organism for sodium chloride in mg/l at 20° and 3° C respectively, were determined by laboratory studies to be as follows: Stictochironomus 788 and 1000; an oligochaete 1576 and 2000; Daphnia magna 200 and 800; Cyclops serrulatus 394; Leucaspisis delineatus 1970; and nitrifying bacteria, first and second stages, respectively, 1970 and 20,000 (127). Adult arctic char (Salvelinus alpinus) taken in summer from Hebron Fjord, Labrador, and Hudson Bay near Churchill, Manitoba, were transferred directly from salt to fresh water under fairly constant conditions. Decreases in blood freezing point and chloride

concentration of about 25 percent were found, indicating that the char is like most other anadromous salmonids in this respect (101).

Twenty-four hr median tolerance limits of bluegills to oil field brines were found to range from 8,100 ppm to 10,500 ppm total chlorides, depending on the source of the brine. Tolerance decreased as the period of exposure increased. It was found that $CaCl_2$ was more toxic than NaCl and that when they were mixed in equal quantities, the combination was less toxic than either individually. It was deemed possible to construct physiologically balanced brines which would not be lethal to certain fresh water fish at 10,000 ppm. Tests with mayfly nymphs indicated that their 24 hr tolerance limit was about 10,000 ppm and their 72 hr tolerance about 3600 ppm chlorides. Thus concentrations which are safe for certain fish are lethal for certain mayflies. Tests with two refinery wastes indicated that they were toxic to fishes (231). Studies in an Oklahoma stream receiving oil well brines indicated the average number of kinds of organisms found in areas, with various concentrations of chlorides, to be as follows: 20,000 to 16,000 ppm -- 4.0; 16,000 to 11,000 ppm -- 4.8; 11,000 to 8,000 -- 6.5; 8,000 to 4,000 — 8.5; 4,000 to 1,000 — 9.3; and 1,000 to 100 ppm -- 13.0 (59).

Dissolved Oxygen

When eggs of the chum salmon (Onc rhyncus keta), which were being hatched at 10° C, were exposed to low DO levels (0.3 ppm) for a period of 7 days and then cultured under normal conditions until hatching was complete, it was found that some monstrosities resulted. At 10° C oxygen levels below air-saturation produced delays in the mean hatching rate.

Low DO stimulates eggs in an advanced stage of development to hatch prematurely. Critical levels of dissolved oxygen were found to range from about 1 ppm in early stages to over 7 ppm shortly before hatching (4). For chum salmon eggs, oxygen uptake is independent of the CO_2 level if it does not exceed 125 ppm. However, at this level there may be considerable mortality (3).

Diurnal variations in DO concentrations are almost directly proportional to the phytoplankton population and to the amount of light during the day (208). A study of a dam near Jinja, Uganda, has shown that in addition to diurnal fluctuations of DO as a result of photosynthesis and respiration, nocturnal cooling of the surface water can cause overturn and the depletion of surface water oxygen (160).

During the fall months large amounts of leaves find their way into streams, lakes, and reservoirs. It has been found that maple leaves under aerobic conditions exert an oxygen demand equivalent to 75 percent of their weight, while oak leaves and pine needles exert a DO demand equivalent to 50 percent of their weight (48).

At 5° C crucian carp (Carassius carassius) tolerated for 2 months low DO levels which they could withstand for only a few hours at 16° C. It is stated that H_2S does not complicate the influence of low DO. The critical tension at 5° C, that is the lowest DO concentration which does not lower the oxygen consumption, was found to be 1.7 ml of O_2 per liter (28). In the transportation of fish it was found that certain absorbents (pulverized earth, activated charcoal and Amberlite) were effective for the absorption of NH_3 and CO_2 and the increase of the survival period. Carp spawn was found to stand a concentration of 20 ppm of dissolved CO_2, 2.5 ppm free

NH_3, and 15 ppm of NH_4^+ in the form of inorganic salts (193). Studies have been made in India to determine the effects of oxygen pressure, free surface area, and water volume on the number of carp fry that may be transported in a closed system (192).

Dissolved oxygen criteria must insure that DO concentrations are favorable at all times and to all desirable species and their different life history stages. These criteria must be based on a knowledge of the environmental requirements of the organisms which are to be protected from pollution. It is suggested that these criteria should be expressed in ppm and should specify favorable levels and the lowest allowable level for short time exposures. It is believed they should not be expressed as average concentrations or percent of saturation. While a great deal yet remains to be learned it is believed that tentative criteria should be set up based on our best knowledge and experience. They can be changed in the future when so indicated by new data. For a well rounded warm water fish population it is recommended that in any 24 hr period the DO shall not be less than 5 ppm for more than 8 hr and at no time shall it be less than 3 ppm. For coarse species this lower value may be 2 ppm. For good salmonid production it is suggested that DO concentrations should not be less than 6 ppm (214).

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Toxic Materials and Wastes

Methods

In streams receiving putrescible wastes there is often a diurnal variation in DO values in certain portions of the stream. For some time it has been known that the DO concentration influences the toxicity of some materials to aquatic life. Experiments were conducted (41) to determine the effect on the toxicity of certain chemicals by periodic lowering of dissolved oxygen to represent conditions in streams with periodic oxygen sag. From a level of 5 to 9 ppm, DO was lowered slowly by the introduction of nitrogen to a level of 2 ppm. This level was held for 2 hours and then increased to the normal 5 to 9 ppm DO. An 8 hr period was allowed for lowering, maintaining, and raising oxygen levels. In the absence of toxic materials these variations in DO levels had no adverse effects on the animals used; however, they did influence the toxic effects of certain materials as indicated by the 96 hr TL_m. Under normal oxygen (5-9 ppm) and low oxygen (2 ppm), the 96 hr TL_m values, expressed as ppm, were for selected materials respectively as follows for fish: $ZnCl_2$ as Zn^{++}, 8.02 and 4.9; Naphthenic acid, 5.6 and 2.0; KCN, 0.45 and 0.12; Potassium dicromate, 320 and 320. For snails differences in 96 hr TL_m values were respectively as follows: Naphthenic acid, 6.6 and 2.0 and KCN 1.08 and 0.48. These results indicate that periodic low DO levels may result in lower tolerance of organisms to some but not all chemicals.

The marine algae are of considerable importance to the Japanese and concern is felt regarding the impact of various wastes on these organisms. The uptake of phosphorus by these organisms measured by tagging with P^{32} was used as a measure of the well being of these organisms and harmful

effects of certain waste material. Wastes tested were sulphite and soda pulp mill effluent, rayon industry wastes, starch mill wastes, H_2S, NaOH, Na_2S, $CuSO_4$, and bleaching powder. All except starch mill wastes were found to be harmful (85). The effects of certain industrial wastes and chemicals on a bivalve were also studied from the physiological standpoint. The opening and closing of the shells of the bivalve were used as a measure of the toxicity of substances. Calcium uptake was also used as a criterion. The velocity of uptake was determined through the use of Ca^{45}, which was dissolved in sea water containing various concentrations of wastes. The bivalves were cultured in these mixtures and their uptake of Ca determined by radiological means (83).

The toxicity of pulp mill wastes is a particularly difficult problem since many constituents of the waste are not known and there may be antagonisms, synergisms, and other reactions. Thus bioassays offer the most reliable method of determining their toxicity potential to fishes (222). At Niagara Falls, N. Y., DuPont de Nemours, Inc. instituted bioassays using fish indigenous to the area to determine the toxicity of their wastes. Carp, perch, and silver bass were used in determining 24 and 48 hr TL_m values for the wastes. Based on the waste evaluation program, process improvements were made to recover valuable materials and combinations of wastes from several processes were used to treat toxic wastes to an acceptable level (187).

It has been pointed out by several workers that TL_m values denote acute toxicity and they alone do not provide a ready means for determining the concentration of a waste which is suitable under conditions of continuous exposure (23). However, the use and value of bioassays in detecting and evaluating toxic waste problems, in selecting waste treatment methods, in

continuously monitoring wastes, and as a tool in the enforcement of pollution regulations, are pointed out (213).

In the future the increasing demands for water will result in more widespread multiple use. This will require the treatment of wastes to protect and preserve reciving waters for selected beneficial uses. The outstanding present problem in the disposal of metal plating wastes is their toxicity to aquatic life. It is believed that bioassay is the most effective and efficient tool for determining the toxicity of such wastes, the effectiveness of treatment processes, and the amounts which can be safely discharged to the particular stream receiving the wastes (212).

Metals

The 48 hr TL_m of hexavalent chromium by 10-11 inch Micropterus salmoides was found to be 195 mg/l. After 2.5 hr exposure to 94 mg Cr/l, there was a slight increase in the oxygen consumption of the fish followed by a gradual decline to 27 percent below normal, after 68 hr exposure. After 84 hr exposure all test fish were dead, there was a widespread destruction of the intestinal epithelium, and the intestinal folds were greatly reduced in size (82).

In tests to determine the toxic effects of $CuSO_4$ on Daphnia, Cyclops, and Chironomids, it was found that the former was most sensitive followed by the Chironomids and then Cyclops. The $CuSO_4$ was more toxic at higher temperatures while equal concentrations differed in toxicity in different waters being most toxic in distilled water, tap water, and pond water, in the order named. Lowering the pH also increased toxicity (78). In experiments with pyridylmercuric acetate (PMA) it was also found that this material

was more toxic at higher temperatures. The 8 hr TL_m was 21.1 ppm at 10° C; 10.8 ppm at 16.5° C; and 5.8 ppm at 24° C. There was also some difference in toxicity for fish of different ages. The 24 hr. TL_m was about 5 ppm for yolk fry; 2.18 ppm for 1-week-old fry; and 3.75 ppm for 2-month-old fingerlings (61). Experiments were carried out with Hg^{203}, labelled n-amylmercuric chloride and mercuric chloride, to study the modes of action of these compounds in some crustaceans. Differences between the susceptibilities of Artemia salina and Elminius modestus to the poisons do not reflect differences between quantities of these compounds which the animals can tolerate in their tissues but are directly related to the rates at which the poisons are accumulated. The Hg penetrates into the tissues and does not act simply by becoming attached to the surface (63).

The river Ystwyth continues to be polluted by effluents from derelict lead and zinc mines 35 years after the end of mining operations. Lead has become negligible but zinc is present in the main stream in concentrations of 0.2 to 0.7 mg/l, according to river level. The flora above the mine is rich but below it is poor in quantity and variety. Bottom samples below the mine indicated animal populations of 161 to 373 organisms per 2500 sq cm of bottom. Brown trout now occur in the river (125).

Bioassays to determine the median tolerance limit of Notropsis hudsonius to sodium arsenite indicated the following TL_m values: 24 hr, 45 ppm; 48 hr, 29 ppm; and the 72 hr value was 27 ppm. Even lower concentrations had a corrosive action on fin and tail tissue after 96 hr. No mortality occurred in concentrations of 15 ppm As, which is the highest concentration used for control of water weeds (32).

In their annual report for 1957, the British Water Pollution Research Board describes their work on the toxicity to fish of metallic salts, which is being carried out at the Water Pollution Research Laboratory (17). It was found that Zn. salts are more toxic to fingerling rainbow trout in soft water than in hard water and that the addition of $CaCl_2$ reduces the toxicity of Zn. There were indications that Zn in suspension exerts as much toxic effect as if it were in solution. Experiments using $ZnSO_4$, labelled with radioactive Zn, have shown that Zn does enter the bodies of fish and can possibly act as an internal poison.

Phenolic Compounds

Investigations of phenols in gas liquors have shown that they are more toxic to fishes than are the equivalent solution of pure phenol. The toxicity of phenols is increased by a reduction in the DO concentration. Biological treatment of gas liquors removed the phenols but not the NH_3 and the waste liquor was still toxic (17)

A screening program was set up for the purpose of finding materials having a selective toxicity for lamprey larvae such that they could be used to kill lampreys without killing fishes. Six mononitrophenols containing halogens were found which were significantly more toxic to lamprey larvae than to other aquatic organisms. Under conditions which simulated actual stream conditions the toxic effects of each of the substances upon fish seemed to be considerably less than those obtained in the jar tests, but for the lamprey larvae they were essentially the same. In the stream tests the selective toxicity for lampreys of 3-trifluormethyl 4-nitrophenol was accentuated (19).

In acute and chronic phenol poisoning of fish there is no bleeding from the gills. The fish die of symptoms which are usual in nerve poisoning. Suffocation occurs with the same symptoms as for a lack of oxygen; that is, too much blood in the gills, and blood coagulation in the heart cavity (110). Sodium pentachlorophenate has been shown to be extremely toxic to fishes. Concentrations as low as 0.04 ppm have been lethal to minnows. Its toxicity is influenced by temperature and pH (26).

Pulp and Paper Mill Wastes

Japanese workers have used paper electrophoresis in the evaluation of the physiological effects of paper mill wastes on fishes. Electrophoresis of the serum of fish subjected to various portions or concentrations of the waste have shown that concentrations of acid or alkali which have affected the paper electrophoretic patterns and damaged gill tissues were almost equal. Further, the pattern for suffocated fish differed from normal fish and fish affected by pulp mill wastes could be distinguished from controls experimentally. By this method the physiological effective concentration of pulp mill waste for fish was estimated to be as low as 30 to 50 mg/l COD value (84).

Studies have been made to determine the constituents of black liquor and their toxicity to fish and bacteria. It was reported that the lignin derivatives were more toxic than the hemicelluloses. More detailed studies were made to determine the toxicity of the turpentine fraction of the black liquor. It was found that the toxicity of pure oil of turpentine was similar to that of the crude liquor but the fraction of the liquor distilled off at 150° to 160° C which should be comparable in composition to the oil

of turpentine was much more toxic. This is attributed to the presence of traces of highly toxic organic sulphur compounds (27). The disposal of wastes from pulp and paper mills is of special interest when receiving waters are important for shellfishes and sport and commercial fishing. Chemical pulping wastes involve problems of low DO, toxicity, and nuisance growths. In the lower Columbia River and in the Spokane River Sphaerotilus problems have developed and fish kills have occurred in some harbors and river estuaries. The depressing influences of pulping wastes on water quality were also reflected by a rapid decline in several oyster producing areas in lower Puget Sound and an inhibiting influence on commercial and recreational fishing activities in much of the lower Columbia River. Research at Bowman's Bay has indicated that the threshold mortality indices for the downstream migration of chinook and pink salmon occurs at concentrations of sulphite waste liquor between 500 and 600 ppm for exposure periods of 30 days or more (159).

Insecticides

Prior to 1944 insecticides were, with a few minor exceptions, inorganic materials. Since the appearance of DDT there has been a constant search for more toxic organic insecticides. While DDT is still the most widely used material many newer materials are being widely used and each year sees an increase in the amount of organic pesticides used. Since these materials are toxic to a great variety of animals and they are now being broadcast over extensive areas they are becoming important as water pollutants. This increase in importance is reflected by a corresponding increase in the literature on their toxic or pollutional effects.

DDT - The use of DDT in the upper Nile did not appreciably affect some of the aquatic macroinvertebrates but others, especially the Ephemeroptera and Trichoptera, were virtually eliminated. As these organisms are important as fish food their destruction was serious from the standpoint of fish production (62).

The toxicity of DDT to brook trout fry, salmon fry, and 1- and 2-year-old parrs was studied in hatchery troughs using large numbers of fishes. DDT applied at the equivalent of 0.5 lb/acre (0.32 ppm) resulted in a 93 to 100 percent kill of salmon and trout fry and 1-year-old parrs. In other series of experiments it was shown that sensitivity of salmon decreased with age and that the LD_{50} was 0.072 ppm. Time for this kill was not stated (89).

Field investigations were conducted to evaluate DDT, dieldrin, and parathion for the control of blackfly larvae in slow moving Florida and South Carolina streams. Parathion at 0.5 and 1.0 ppm eliminated all larvae in Florida in 1.6 miles of stream after a 5 minute application but did not exercise control 2.3 miles downstream even with applications up to 24 minutes. In South Carolina 10 and 20 minute applications gave control over 2.8 miles of stream which is about ten times that secured with DDT (68).

In the northwest Miramichi watershed which was sprayed in 1954 and again in 1956, there was a serious reduction in the stream bottom fauna. Annual seining showed that large parr were very scarce in 1956. Small parr resulting from the 1955 hatch were more abundant, averaging 37 per 100 sq yds. They were thin and in poor condition. Fry of the year were very scarce in the sprayed areas but were present in about half normal abundance in the areas not sprayed since 1954. In the area sprayed in 1956, they

averaged 2/100 sq yds. The 1954 spraying had serious effects on the stream insects and these effects were still evident in 1956. Caddis flies were eliminated in 1954 and had not reappeared in 1956. Young salmon are directly affected by DDT spraying and they are also adversely affected by a reduction in the bottom macroinvertebrates (5). The use of DDT for the control of the green chironomid Tanytarsus lewsii resulted in large fish kills. The DDT was applied at a rate to give a concentration of 0.09 ppm and 10 miles downstream the concentration was 0.017 ppm. Fish died 8 miles downstream (37). The disposal of chlorinated hydrocarbon wastes at sea resulted in toxicity to plankton organisms (118).

Toxaphene: Eight alkaline lakes in British Columbia were treated with Toxaphene at concentrations of 0.10 to 0.01 ppm. At all concentrations most of the fish which were killed died within 120 hrs. All fish were killed and the lakes were still toxic to fish 8 or 9 months later. Amphipods were eliminated at all concentrations and were still absent 9 months after poisoning. Dragonflies, damselflies, and midge larvae were killed at a concentration of 0.03 ppm (206). In Michigan lakes which were treated with 0.010 to 0.025 ppm of emulsifiable Toxaphene the small fish died before the large ones. No mortality was observed in a lake treated at the rate of 0.002 ppm but the small fishes were killed in one treated at the rate of 0.005 ppm. These findings suggest that a concentration of 0.005 ppm Toxaphene can be used to reduce the population of small fish in hard water lakes without seriously affecting the large fish (86).

Dieldrin: The airplane application of Dieldrin pellets at the rate of 1 lb of the technical material per acre resulted in a substantially complete fish kill in 2000 acres of Florida east-coast tidal marsh. It was estimated

that 20 to 30 tons of fishes were killed. Mollusks seemed to be unharmed by the treatment but crustaceans were virtually exterminated. The entire aquatic crab and fiddler crab populations were annihilated. Repopulation by fishes began slowly about 4 weeks after the kill (108).

Other Insecticides: Laboratory tests were made with BHC to determine its toxicity to shrimp. For P. setiferus the 24 hr TL_m was 35 ppb and it was 400 ppb for P. aztecus (50). Larvicidal concentrations of DDT were very toxic to Tilapia melanopleura, T. macrochir, and T. pangani. Two percent Dieldrin granules at dosages of 5 to 10 lb/acre were toxic to all three species. A 3 percent BHC powder applied at the rate of 1 lb/acre/week for 16 weeks did not kill the fish (224).

Bioassay to determine the toxicity of endrin to fishes showed that it was less toxic at lower temperatures. The 48 hr TL_m values for carp fingerlings were 0.14 ppm at 8° C, 0.006 ppm at 18° C, and 0.005 ppm at 28° C. Similar experiments showed carp eggs and fry to be far more resistant to endrin than fingerlings. The 24 hr TL_m values were: for eggs, 20 ppm, for 4 day fry, 4.2 ppm, 5 day fry, 0.061 ppm, and 2 to 2½ inch fingerlings, 0.005 ppm. When endrin was applied to rice paddy fields at 1 or 2 lb/acre, toxicity to fish remained for more than a month (122).

Japanese workers determined the toxicity of 11 pesticides to 4 species of fish and estimated TL_m values for 3, 6, 12, 24, 48, 96, and 240 hrs. Of this group of 11 insecticides including, DDVP, Diazinon, Dipterex, Ethyl Parathion, Gusathion, Metasystox, DDT, γ-BHC, Aldrin, Dieldrin, and Heptachlor, it was found that Aldrin, Dieldrin, and Gusathion were most toxic (132). Some of the same workers studied the toxicity of 14 agricultural control chemicals to Daphnia by means of bioassay. The amounts in -

micrograms of each material calculated to be safe for Daphnia were as follows: DDVP, 0.2, Diazinon <0.8, Dipterex, <0.25, Ethyl Parathion, 0.5, Gusathion, 4.3, Malathion, 0.2, EPN, <0.1, DDT, <2.2, γ-BHC, <100, Aldrin, <4, Dieldrin, <250, Endrin, 50, Heptachlor, 20, and Derris, 0.1 (148).

Organic Phosphorus Insecticides

Goldfish and the Japanese killifish were kept about a month in sublethal levels of parathion and its effects on the fish observed. At concentrations one-thirtieth the 48 hr TL_m the movements of the gills and pectoral fins were retarded and feeding and growth were decreased. The results show that the permissible concentration of parathion is far lower than one-tenth the 48 hr TL_m (149). Bioassays were made with 10 organic phosphorus compounds to determine their relative toxicity to fish. It was found that the toxicity of these materials varied over a wide range, the 96 hr TL_m ranging from 0.20 to 121 ppm. No relationship was apparent between toxicity and chemical structure. With one exception water quality had little apparent effect on toxicity. Bluegills were more sensitive to several of these compounds than were fathead minnows. The organic phosphorus compounds were in general less toxic to fish than the chlorinated hydrocarbon insecticides (113).

Sevin: A new insecticide called Sevin (1-naphthyl-N-methylcarbamate) has been found to be fairly nontoxic to some fishes. Ethanol solutions of Sevin were used in bioassays with goldfish. It was found to have a TL_m of 28 ppm. The wettable powder had a TL_m of 14 ppm (111).

Toxic Materials Produced by Algae

A unialgal culture of Microcystis aeruginosa which is toxic when injected intraperitoneally into white mice has been isolated. There seems to be two toxic fractions, a slow and fast death factor. The latter is an endotoxin which is detected only where cells become leaky or disintegrate. The concentration of the fast death factor in the cells varies with the developmental stage of a culture (121). Methods have been developed for extraction of the toxin from cultures of Gymnodinium veneficum. The toxin is soluble in water and the lower alcohols but insoluble in ether and chloroform. The toxin as it occurs in sea water is not the same as paralytic shellfish poison. It is believed to attack the nervous system (1). Gymnodinium brevis has been shown to be toxic to 6 species of fish. It is concluded that this dinoflagellate is the direct cause of the mass mortalities of fish and other marine animals in the Gulf of Mexico. Toxicity of the organism does not depend on the presence of living organisms (186). "Red tides" which have cuased fish mortalities are world-wide in distribution. The blue-green alga, Trichodesmium, is the causative organism along the east coast of South America, and a few other records refer to organisms belonging to the Chloromonadineae and Chrysophyceae which cause trouble off the coasts of India and Eurasia (20).

Other Materials

Studies have been made on the toxicity of Cl_2 to fish. Results indicate that residual Cl_2 at 0.1 ppm is markedly toxic to trout particularly if the DO is low. At all concentrations of DO used, a given concentration of Cl_2 was more toxic at pH 6.3 than at either pH 7.4 or 8.2 (17). The

toxicity of Cl_2 wastes in rivers does not depend directly upon the amount of Cl_2 added but upon the concentration of residual Cl remaining in solution (152).

Rainbow trout were continuously exposed to levels of 0.035 and 0.070 ppm of Separan for a 4-month period with no mortality. Slight growth retardation occurred at the concentration of 0.070 ppm (168). The herbicide Delrad at concentrations of 0.25 and 0.3 ppm killed large amounts of Pithophora in ponds but the effects were of short duration, 1-3 weeks. As many as 3 applications of Delrad at 0.3 ppm in bass brood ponds did not affect spawning of bass, hatching of eggs, or survival of fry and fingerlings. Four applications did not appear to affect bluegills. Minimum lethal concentration for bluegills and largemouth bass is about 0.65 ppm (143).

Sodium cyanide has been used as a fish poison in fish management work. At 1 ppm it kills fishes at a variety of temperature and pH conditions (35).

In connection with studies of chemicals for the control of diseases and parasites of channel catfish, bioassays were conducted to determine the toxicity of several compounds to fingerling channel catfish. The TL_m values found for the different materials are shown below (60):

		TL_m Values in PPM		
Materials	Temp.	24 hr	48 hr	96 hr
Pyridylmercuric Acetate ("PMA" 80% active)	75°	3.8	-	.49
Trypaflavine	68°	11.5	6.8	4.9
Acetic Acid	77°	446.0	388.0	270.0
Malachite green (oxalate salt)	77°	0.14	0.14	0.14
Formalin	77°	87.0	69.0	69.0
Phenylmercuric Acetate (10% solution)	68°	1.46	0.78	0.58

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Organic Wastes

Effects of Organic Enrichment

It has been well established that raw sewage or the effluents from sewage treatment plants contribute fertilizer in the form of nitrates and phosphates and other growth promoting substances to a receiving water. The sum total of these additions frequently results in a highly productive or eutrophic receiving water. Ill effects from sewage, mainly due to algal growths, including toxicity, tastes and odors, and increased BOD may outweigh benefits such as oxygenation, mineralization, and production of a food chain. Perhaps what is needed is treatment so complete as to remove all the nitrogen and phosphorus (141). Some lakes in the Swiss area have been converted from oligotrophic to eutrophic conditions by the influence of civilization, mainly by increased discharges of organic matter and phosphates (164). Limnological and biological changes in Lake Zurich since 1896 when the first mass invasion of Tabellaria fenestrata and the first deposit of septic sludge was observed are described. The lake is now meromictic and meso-eutrophic but good water supplies are still being secured.

Construction of additional sewage treatment plants is needed and the increase in industry may cause further deterioration (139).

A year round study was made on the Mad River, a stream receiving heavy organic enrichment and also paper mill waste discharges. Major

effects were a decrease in dissolved oxygen of from 2 to 9 ppm and a corresponding increase in free CO_2 from 0 to 10.5 ppm. In addition paper mill wastes blanketed the bottom with paper fibers, making it totally unsuitable as a habitat for most species of macroinvertebrates. A striking difference in the qualitative and quantitative makeup of populations of aquatic macroinvertebrates was observed above and below major waste effluents. The largest number of species, 58, was taken in the headwater section. Of this number nearly half were mayflies, stoneflies, caddis flies, and certain beetles. Only 14 species were collected at any one time in a heavily polluted area (93). Studies of a river in Wisconsin showed a marked change in the type of algae from source to mouth. Blue-green algae predominated near the source (a lake) and green algae characteristic of moving waters near the mouth. The production of oxygen from live algae exceeded the oxygen usage in BOD reactions of both live and dead cells, resulting in a significant net gain in dissolved oxygen (229).

In recent years, Florida has had an increasing problem with "blind mosquitos" or chironomid midges which are a nuisance when overly abundant. It appears that overproduction of midges is a product of excessively enriched waters and may be the result of sewage effluents which are rich in nitrogen and phosphorus. Controls with DDT or BHC were ineffective as the midges developed a resistance. Investigations are underway in 19 lakes to determine causes and methods for control (183). Masses of chironomid tubes were observed floating in a channel carrying the effluent from an activated sludge plant. The tubes were composed of sludge that had settled in the bed of the channel. It is suggested that the release of large amounts of organic matter from the benthos in this manner is likely to lower the

concentration of dissolved oxygen in the water and thus may produce conditions adverse to fish (73).

A startling effect of biological imbalance in streams which has become a serious problem below many industrial outfalls is the development of massive growths of filamentous slime encased bacteria. The effect of a Rayonier, Inc., plant in the production of Sphaerotilus in the receiving stream and the factors which may be involved were studied (44). Biological imbalance caused by substantial amounts of wastes in streams offering high dilutions in the presence of sufficient dissolved oxygen, short chain organic compounds, near neutral pH, and other known and unknown conditions may cause infestations. Similar studies on the composition and causes of slime formation in paper mills were made in Czechoslovakia, and various species of bacteria, fungi, and protozoa were identified. The effectiveness of various slime control agents were tested and effective treatment methods determined (147). In a river in Sweden, a mass development of Achlya prolifera was found below a factory manufacturing wood fiber sheet. This fungus appeared in parts of the river in which there was a fair flow and good aeration. Further downstream where the river was partly dry, this fungus was replaced by Leptomitus lacteus. Proteins were almost completely absent in the river water and the main source of nutrient matter appeared to be the dissolved simple sugars (180).

The self-purification capacity of a stream is its ability to utilize continually and to render innocuous by physical, chemical, and biological processes dissolved and suspended materials which are added to it. Biological surveys and investigations can be valuable tools for the determination of the effectiveness of natural purification and the discovery of

factors which cause undesirable conditions or limit the purification processes (215). Elevation of pH was suggested as a possible method for removal of ammonia from sewage effluents (137).

Indicators of Pollution

The biological examination of polluted waters to determine the extent of pollution and hence the effect on fish received some attention. Various organisms including fungi, bacteria, algae, protozoans, and bottom animals were used as indicators. Studies were made on milk processing plants which encourage extensive growths of Leptomitus lacteus and sugar refineries and distilleries which cause growths of Sphaerotilus natans. Detailed examination of the form in which the organism occurs indicates the extent of pollution (232). The biological proofs of pollution should assume the same value given to chemical analyses.

The algal vegetation of the Saline River, Michigan, was studied over a period of 18 months along with the physico-chemical variables which might influence algal growth. The upper river is unpolluted but the lower course is polluted with industrial waste waters and sewage which produces a change to a pollution resistant flora. Some organisms were found to be markedly resistant to chromium and other polluting ions (29). Sewage from one half million people is discharged at the head of Oslofjord, Norway, which causes very heavy pollution. Most littoral algae show an inner limit which must be considered an effect of pollution. Twenty-four species of algae were studied closely and tolerant and intolerant forms listed. Since 1897 several species of algae have disappeared from the fjord probably due to pollution (103).

In a study of a small artificial pond, the nature and amount of organic nutrients in the water appeared to influence the numbers of euglenoids and ciliates. The amount of phosphorus seemed to influence which phytoplankters appeared. Chrysomonads were not found when the water contained more than 0.02 ppm phosphate but cryptomonads and diatoms increased at this concentration (21). Slight environmental changes can promote rapid change, reduction, or subsidence of a population. Activated sludges produced in laboratory scale plants treating trade waste waters were examined for the presence of stalked protozoa. The author considers that these organisms can be useful indicators of the condition of activated sludge (167).

In a study of the Mad River in Ohio, a total of 166 species representing 122 genera of macroinvertebrates were collected and identified. The largest number of species was taken in the clean headwaters. Very few species were found in heavily polluted sections but some of them occurred in large numbers. By considering the species composition, abundance, and adaptations of the macroinvertebrates collected in the various pollutional zones which were indicated by physico-chemical tests, it was possible to classify such organisms into three categories based upon their reactions to organic enrichment; namely, clean water, facultative, and pollution preferring categories (93). Bottom faunas in polluted New Zealand streams were studied to devise biological criteria for evaluating the extent and severity of organic pollution. In grossly polluted areas, the fauna is comprised largely of tubificid worms and sometimes includes naiad worms and certain chironomid larvae. In less polluted streams, a molluscan fauna is commonly present. With decreasing degrees of pollution caddis

fly larvae and many other organisms are found to reappear, with the sensitive mayfly group appearing last (114).

Based on a study of several lakes, one author states that the causes of eutrophic conditions in lakes cannot be judged by examination of present chemical and biological conditions only but that examination of the history of the development is necessary. This can be done by examination of cores of bottom sediments taken by borings (235). Methods developed for such investigations are described.

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Radioactive Wastes

A review of the present situation with respect to the disposal of radioactive wastes was made and the problems that confront fisheries scientists pointed out (77). At present only Canada, Russia, the United Kingdom, and the United States are disposing of any substantial quantity

of radioactive wastes but other nations will soon be doing the same. There will undoubtedly be a large increase in radioactive wastes and the oceans are the obvious place to dump this material. The disposal of these wastes is today a subject of great importance to oceanographers, biologists, and other scientists of the world. The propensity of fish and living organisms to concentrate radioactive elements is one of the dangers inherent in the disposal of radioactive wastes at sea. The problem is very complex and an enormous amount of research and investigation will be necessary to insure that, as the volume of radioactive material grows, it can be disposed of safely. Some radioactive materials introduced into aquatic environments may be accumulated by the organisms. The amount of accumulation will vary over many orders of magnitude, depending upon the kinds of isotopes involved and many physical, chemical, and biological factors (69). The process of adsorption and absorption are of major importance in the uptake of radioisotopes by plants but appear to be of less importance than the food chain in the uptake by aquatic animals. The concentration of radioactive substances will vary between species and tissues and will fluctuate according to food habits, life cycles, and seasonal changes. Where the turnover rates of certain isotopes can be measured, inferences can be drawn on feeding habits of organisms.

In the treatment and disposal of radioactive wastes from the Chalk River, Ontario, plant of Atomic Energy of Canada, Ltd., it is considered that radioactive waste waters can be safely and effectively disposed of

by utilizing the principles of segregation and reduction of wastes at their source, by taking advantage of the natural properties of the materials and by following an intensive and continuous sampling program (170). At this plant, the limited discharge of fission products to the Ottawa River has resulted in concentrations of radioactivity far below the permissible levels allowed in water. No accumulation of radioactivity in the river organisms has occurred during the years in which the plant has been in operation. During summer, some radiophosphorus is taken up by organisms, but by autumn the radioactivity disappears, owing to the lowered metabolism of the organisms and the short half life of radiophosphorus. A survey of the radioactivity in the waters of the North Equatorial Current from the Marshall Islands to the Marianas Islands was made in September 1956 (198). The general pattern of distribution of radioactivity shows a sharp decrease east of Bikini and a gradual but irregular decrease west of Eniwetok. A slight degree of contamination was indicated as far west as Guam. Nonfission products account for a large proportion of the radioactivity in plankton and fish samples.

The uranium ore refining industry is an important source of radioactive liquid wastes. There are 14 operating mills with capacities ranging from 300 to 3,300 tons of ore with present capacity about 15,000 tons per day. During 1955 and 1956, surveys were carried out to determine the effects of wastes discharge on streams (219). Mills may vary

greatly in the discharge of radioactive materials and some radium concentrations were found in excess of usually accepted maximum permissible amounts. Samples of algae, bottom animals, and fish were found to concentrate radium to a considerable degree. Radium content of algae samples taken below one mill was 1500 times that in samples above the mill. Wastes from uranium mill operations have definite public health significance primarily because of the very long half-lived materials involved.

Numerous laboratory studies were made to determine the uptake of various radionuclides by different organisms. A study of the uptake of 3 neutron induced radionuclides (Zn^{65}, Fe^{59}, and Co^{60}) and a 2-month-old mixture of fission products by the clam demonstrated the ability of this marine animal to concentrate rapidly significant quantities of these radionuclides in both shell and soft tissue (100). The uptake of radioactive material in the soft tissue is a metabolic incorporation, while the higher uptake by the shell appears to be a surface adsorption phenomenon. The ability of the clam to concentrate radioelements to a high degree makes it valuable as a biological indicator of radioactivity. Zinc concentrations in sea water and in shellfish samples, collected from inshore waters along the Atlantic and Gulf of Mexico coasts are reported (51). Oysters, clams, and scallops concentrate large amounts of this trace metal, the oysters containing the greatest amounts. Radioactive Zn added to water was rapidly taken up in large amounts by shellfish. Nitzschia closterium, apparently concentrates large amounts of Zn^{65}, thus allowing

its transfer to marine animals. Marine fish quickly take zinc into the body from the digestive tract but much of it is excreted rather promptly. A small percentage was retained for many days. To determine whether marine fish require calcium in their diet, or whether they can take up an adequate amount from sea water, non-feeding fish (Tilapia mossambica) were placed in artificial sea water containing Ca^{45}. The fish took up about 60 percent of the Ca^{45} in the water. It is concluded that marine fish can take up Ca from the water and do not need a dietary source of this element (31). From a similar experiment with strontium, it was concluded that marine fish discriminate against strontium in favor of calcium, either by excreting it faster or by absorbing less. Daphnia and Cyclops placed in water containing $CaCl_2$ labelled with Ca^{45} were found to concentrate the calcium, so that after 47 hours they contained about 138 mg/100 gms of fresh weight. When transferred to nonradioactive solutions, the concentration of radioactive calcium in their bodies was halved in 30 minutes. Guppies fed on Cyclops which had concentrated Ca^{45} took up the element but the process was slow. Direct uptake from water by the guppies was more rapid (133). Unialgal cultures of Euglena and Chlorella grown in three concentrations of Cs^{137} (1, 5, 10 μc/l) demonstrated that the uptake was linear (227). Structural components persist in dead Chlorella which absorb cesium from very dilute solutions and the absorption is not affected by the concentration of potassium in the medium.

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MICROBIOLOGY

In 1957, 4 disease outbreaks were reported (67) for which water was the vehicle of infection. In one outbreak, two persons with typhoid fever had used water from a dug well presumably contaminated by a chronic carrier. Gastroenteritis of unknown etiology occurred in two groups using water from wells that showed evidence of fecal contamination. One small group of enteritis cases appeared among passengers on a plane, where the drinking water was the probable source.

Eighteen cases of infectious hepatitis (not included in previous report) in Davies County, Kentucky (158) were investigated, and the epidemiological evidence indicated that at least 9 of the cases were due to ingestion of water from private wells contaminated from the first known case. It is believed that water-borne hepatitis may be more frequent than is reported, particularly in rural areas where water supplies are often poorly protected.

An epidemic of enteritis was caused by a cross-connection of a city water supply and a sewage polluted bayou through an underground lawn sprinkling system (155). No specific etiological agent was isolated from the patients, however, when the cross-connection to the city supply was removed, the outbreak promptly subsided.

Typhoid bacilli have been demonstrated in river and well water in concentrations as low as 10 to 100 organisms per milliliter by use of the "increase in phage titre reaction" (99). The sensitivity of this increase in phage titre reaction is said to be considerably greater than that of bacteriological examination, and depends on the character of the typhoid strain and the presence of other microorganisms in the water. Weber (225)

in Germany was able to demonstrate Salmonellae in surface waters most efficiently by use of solid media and membrane filter technique. S. paratyphi B persisted as long as 3 months and was more resistant than S. typhosa. Viability of the organisms depended both on the conditions of the water and on temperature. Papp (174) determined the Salmonellae content of water and sludge samples from the river Oker and its tributaries. The highest Salmonella loadings were found below sewage-works outfalls. Infection of the stream persisted 15 to 21 miles below the point of sewage discharge. If self-purification had proceeded to the meso-saprobic stage, Salmonellae were absent or only sporadically present. Neither natural or artificial biological treatment removed the Salmonellae. Reut (189) showed that the presence of humus in water increased the survival time of S. typhosa, S. dysenteriae flexneri and E. coli, while Shrewsbury and Barson (199) found that temperature and pH of the water were important factors affecting the viability of S. typhosa, S. dysenteriae varieties shiga, flexneri, boydii, sonnei and V. cholera. Luria and Burrous (146) reported that a number of Shigella strains were capable of mating with E. coli. Matings resulted in formation of hybrids, which exhibited new combinations of characters typical of Shigella with characters typical of E. coli. The results suggest a possible role of hybridization occurring in nature in the evolution of the Enterobacteriaceae and in the origin of aberrant and intermediate strains of enteric bacteria. Ettinger (74) pointed out that the recurrent pattern of oxidative food usage by microorganisms and oxidative destruction of cell substance are essentially similar in natural stream purification and in activated sludge or trickling filter systems.

In July 1955, 73 cases of leptospirosis, type canicola, occurred among the inhabitants of Rostov-on-Don region (234). The spread of the leptospirae was by way of a faulty water tower, contaminated by underground water as the result of heavy rains. Five strains of Leptospira pomona were isolated from stagnant and rapidly flowing waters in 4 areas by Gillespie et al (97). The source of infection was probably the urine of cattle suffering from leptospirosis.

Examination of school children in Swaziland (179) revealed high rates of infection with Schistosoma mansoni and S. haematobium. The spread of infection was fostered by the use of rivers and canals for bathing and washing purposes. Preventive measures such as provisions for more suitable bathing, washing and latrine facilities, control of waste waters, and the use of molluscicides were recommended.

A collecting bottle for the sampling of water for microbial examination was described by Potter, Osterhoudt and Baker (182). The collector was designed to insure uncontaminated samples at various depths and to withstand pressures of more than 100 lbs per sq. in. The use of a chelating agent, ethylenediaminetetra-acetate (EDTA), for preservation of coliform organisms in water samples was investigated by Dardanoni and Cordone (66). Eighty-six percent of the chelated samples gave coliform counts equal to or higher than the untreated samples, and 58 percent gave significantly higher counts. Hoather (116) found that the bactericidal action of copper can be prevented by the thiosulphate used for neutralizing chlorine (100 mg/l). The bactericidal action from zinc can be prevented by a small quantity of sodium phosphate in the sampling bottle.

Kichenko (131) stated that all varieties of coliform bacteria can serve as indicators of fecal contamination of water, while Burdin and Schmitt (38) recommended immunological differentiation of E. coli. When pathogenic E. coli are found, a single organism is enough to condemn a water source for drinking use. The identification of E. coli by production of indole after 48 hrs. incubation at 44°C was proposed by Buttiaux, Samaille and Pierens (40). Clark et al (55) and Geldreich et al (94) did not recommend boric acid lactose broth fermentation at 43°C in 48 hrs. and positive reactions in EC medium in 24 hrs. at 45°C as single specific tests for accurate identification of E. coli (++-- IMViC type), however, the tests did appear suitable for rapid enumerations of E. coli in the investigation of field problems and other kinds of control work.

In testing beach water samples for coliforms, Christovao (52) observed fewer presumptive and confirmed positives with lauryl tryptose broth than with lactose broth. Gabbrielli and Giunti (87) in comparative testing of media for enumeration of coliforms, found lauryl sulfate medium best. MacConkey medium was more selective and less sensitive than lactose broth. The Public Health Service Water Sub-Committee of Britain (184) did not recommend lactose glutamic acid as a satisfactory substitute for MacConkey broth, although the latter in the presumptive coliform test slightly suppressed both B. coli I and other true coliform organisms. Simpson and Cales (200) showed that brilliant green bile broth was slightly better than MacConkey broth in the 6 hr. incubation period for the identification of B. coli type I and that indole broth was better than either MacConkey or brilliant green bile broth for rapid confirmation tests. Jameson and

Emberley (124) suggested that the suitability of Teepol formulations, other than Teepol 530 and L, should be tested before use in culture media. The reliability of coliform density tests was evaluated by McCarthy, Thomas and Delaney (150) who concluded that there is an enormous area for improvement in the estimation of the sanitary pollution parameter. A method is needed that will embody greater precision than the MPN procedure and that will also allow the cultivation and enumeration of all strains of the coliform group.

Resistances of enteric viruses to chlorine (129) exhibited differences according to strain rather than type. Strains in order of increasing resistance were Coxsackie B 5, polio 1 (Mahoney), polio 2, Coxsackie B 1, polio 3 and polio 1 (MK 500). Rises in pH value of one unit above pH 7 more than doubled the contact time required. Bacterial viruses, E. coli phage T 2, S. typhi phage E 1, S. typhimurium phage 34 and S. sonnei phage IV at pH 7.2 and 6°C were reduced 1000 fold when exposed to .03 to .05 ppm free chlorine for one minute (81), i.e., an amount of the same order of magnitude required for E. coli, S. typhimurium and S. sonnei. The inactivation of B. globigii and B. anthracis spores by free available chlorine was markedly slowed by lowering the temperature or increasing the pH (34). To effectively inactivate bacterial spores, the reaction should be carried out at pH levels of 7 or less. Quantitative studies on the reaction of radioactive chlorine with bacteria in water disinfection (80) showed that on an average, 10 to 25 percent of the free available chlorine was found in the bacteria after 5 minutes exposure. Chang (45) has described the relative cysticidal and viricidal efficiencies of various chemical species of titrable iodine in water. Equations are given for computing cysticidal and

viricidal titrable residual iodine in solutions of known amounts of iodine and pH.

Stumm (207) reviewed the production of ozone, its cost, chemical properties, solubility in water, and decomposition as well as problems of analysis. He indicated that ozone showed a more rapid action than chlorine in killing some of the more resistant organisms such as bacterial spores and cysts of E. histolytica. Three years use of ozone in the disinfection of water for the City of Paris was detailed by Guinvarc'h (106). The rate of treatment averaged 1.1 ppm and varied from 0.6 to 1.5 ppm depending on the pollution load of the raw water. Treated water never showed the presence of E. coli, and in comparison with filtered water, Cl. perfringens was reduced 50 percent.

A silver preparation "Micropur" was used with a peroxide compound in the disinfection of wells after pollution by flood water (162). Intermittent treatment of two to three doses showed definite disinfecting action even under unfavorable conditions. Reduced temperature and increased pollution decreased efficiency of the disinfectant. A modern Katadyn filter removed S. enteritidis and S. thompson from artificially infected water (151), but Staph. aureus and Strep. faecalis were not removed. Kirstensen and Skadhauge (138) claimed that Salmonellae dysentery and cholera organisms in drinking water can be destroyed by hydrochloric acid in a concentration of 0.06 N after 10 minutes exposure time. The method is said to be unreliable for destruction of poliomyelitis and other viruses and for cysts of E. histolytica.

Chang et al (46, 47) showed that temperature, pH, rate of stirring, buffering salts and concentration of flocculent affected the removals of bacteria, Coxsackie A 2 virus and Staph. albus phage in water by flocculation.

with aluminum sulphate and ferric chloride. Under optimum conditions, 99 percent or more of the viruses and bacteria were removed in the laboratory investigations. The critical time for formation of coagulant-microorganism complex in the removal of viruses and E. coli by practical dosages of alum at 25°C was confined to the first few minutes after addition of the coagulant.

Although Endo type media has certain disadvantages when used with membrane filter procedures, Roggenkamp (191) and Papavassiliou (173) obtained excellent results by careful attention to filtration and incubation techniques. Fifield and Schaufus (76) described an improved MF-Endo medium for enumeration of coliform organisms, which produced excellent, clear-cut sheen colonies in 20 to 22 hrs. incubation and did not require preliminary enrichment medium or incubation period. Lang (142) and Gohar and Eissa (98) found MF procedures superior to tube methods in the examination of "clean waters", but preferred titration methods for highly polluted waters. The Metropolitan Water Board of London (10), because of economic advantages and convenience, recommended MF procedures for the examination of selected types of samples. After comparing coliform counts in water by membrane filter and most probable number methods, Akman (2) concluded that it was not advisable to depend on MF procedures alone, however, the filters used were several years old and not of type and quality currently available.

Jones (126) discussed the use of membrane filters for the examination of potable water for the U.S. Air Force. Nine significant advantages and five disadvantages of using the MF instead of MPN methods were given, indicating the high desirability of adopting the MF field kit as a water testing device. In November of 1957 the American Water Works Association

accepted the membrane filter procedure as an alternate to the completed tests when specified conditions were met (9). Hazey (112) presented an operator's viewpoint of the MF technique and concluded that the daily bacteriological examination was more interesting and became a pleasant assignment. The ability to count actual colonies has more meaning to the operator than an estimated number from a table.

SLIME GROWTHS

Sphaerotilus and associated slime bacteria may be found in streams in many parts of the world but frequently escape notice when existing as free organisms in low density. However, under selected environmental conditions and in the presence of relatively low concentrations of domestic sewage or industrial wastes, sudden explosive growths may occur in a stream. These growths appear as attached or floating plumes or masses of dirty colored material. They rapidly accumulate in sufficient quantity to decrease the usefulness of the stream for recreational use, produce an unsightly appearance, disturb aquatic life and lead to the development of sludge banks downstream. The anaerobic decomposition of such sludge banks can produce offensive conditions many miles from the place of the original growth. When the growth reaches a nuisance level, it is properly described as a Sphaerotilus infestation. These infestations may occur periodically, occasionally, seasonally or for long periods in a chronic condition. Such infestations present formidable control problems in many streams.

The best current review of slime infestations by Sphaerotilus and Leptomitus is the report by Harrison and Heukelekian (109). This paper is highly recommended for the detailed summary of problems, methods, morphology, taxonomy, nutritional requirements, mineral needs and the known environmental effects on the Sphaerotilus and Leptomitus plus the citation of 52 references in the text and an additional 32 references by title. It serves equally well as a valuable review for the experienced investigator and as a basic introduction of slime infestation problems and methods for those newly undertaking investigations in this field.

Considering the nuisance problems created in streams in many parts, there have been remarkably few reports in the current year's technical literature. Perhaps this emphasizes the difficulties encountered in the investigation of the causes and control of slime infestations in streams.

Cawley (44) made a careful investigation of an infestation occurring in the downstream area from a paper mill outfall on the Altamaha River in Georgia. The Sphaerotilus did not reach nuisance levels until the mill had been in operation approximately 18 months. The organism, identified as Sphaerotilus natans, was studied in the stream environment and in the laboratory on media containing the organic compounds found in the waste. Control of the growth by intermittent discharge of waste for 8 to 10 hours/day reduced the growth but did not prevent it even when timed to begin after the river had cleared following a mill shut-down. After the growth had been established in the river, a trial run of intermittent discharge of 12 hours/day of waste had no appreciable control effect. Growths in this river were affected by DO, short chain organic compounds, temperature, pH and flow rates. It was also recognized that unknown environmental factors exist which markedly affect the infestation, and at present no satisfactory theory can be developed to explain growths of Sphaerotilus natans.

Streams in Germany receiving paper mill wastes or wastes containing short chain alcohols frequently developed infestations with Sphaerotilus natans as the predominating organism according to Höhnl (117). This investigator was of the opinion that, in addition to the usual organic and inorganic nutrients and suitable environmental conditions, 18 amino acids and a sugar content of 20 to 50 µg/l were necessary for growth.

Sphaerotilus natans was present in pH ranges of 5.8 to 9 and Sphaerotilus dichotoma at approximately pH 6.4 but when the pH range reached 5.2 to 5.6, the predominating organisms were species of Fusarium and Mucor. Use of chlorine at the maximum permissible concentration in streams (1 mgm/l) was not effective as a control measure.

Pooth (180) reported an infestation in a Swedish stream receiving wastes from a wood fiber plant. The predominating organism was Achlya prolifera immediately downstream which was replaced by Leptomitus lacteus. The simple sugars contained in the factory waste were presumed to be the main source of nutrients which upset the biological balance in the stream. Pooth believed pure culture studies on different nutrient substrates might give the reason for the mass growth.

Sphaerotilus and Leptomitus species were considered by Wurtz (232) to be indicators of organic pollution in the stream since growth can only occur in the presence of organic acids, a good nitrogen source and mineral salts. Infestations occurred in French streams polluted with wastes from milk processing plants, sugar refineries or distilleries. The Sphaerotilus natans appeared in more polluted streams while less pollution usually produced another physiological form known as Cladothrix dichotoma. One stream was described which received sugar wastes that had the Sphaerotilus give way to the Cladothrix toward the end of refining operations.

Beckling, Ferguson and Kaplan (24) report a pH limit of 4.6 to 8.0 and an Eh limit of 200 to 500 v. for growth of the genera Sphaerotilus and Gallionella in estuary studies.

Wolfe (230) cites the work of Pringsham showing iron can be deposited in the Sphaerotilus natans sheath but holds the opinion that it is extremely

doubtful if the organism can actually utilize the energy of iron oxidation. Skerman, Dementjera and Carey (202) in similar work with sulfur demonstrated the deposition of sulfur granules in sheathed Sphaerotilus natans when grown in an atmosphere containing H_2S but express doubt that the engorged cells are viable.

Probably the outstanding report of the year from a practical control viewpoint was presented in the Progress Report of the Columbia River Study 1956-1958 (16). Tentative results of this investigation suggest the phosphorus concentration appears critical in limiting growth in systems containing above minimum concentration of ammonia-nitrogen; abrupt increases in flow velocities increase floating masses downstream; dry sulfite solids of 5 mg/l support growth and may occur at 1.3 mg/l; nitrogen and phosphorus essential for growth are not present in spent sulfite liquor; and, intermittent discharge on a 1 day discharge with two or more days holding was an effective control measure in laboratory experiments while 12 hours discharge and 12 hours holding time were ineffective.

Summary

Slime . festations by Sphaerotilus natans and associated bacteria may occur in relatively good quality waters where wastes are received from wood processing plants, paper mills, milk processing plants, sugar refineries or distilleries. These infestations have many common characteristics but there are others that are unique to the individual stream. There is no doubt of the existence of unknown environmental conditions which are of major importance of determining whether an infestation will occur in a specific stream. The slime bacteria have voracious appetites for a variety

of organic substances in various substrates. Satisfactory control measures applicable to streams have not been developed. Intermittent discharge of 12 hours and 12 hours retention has little or no value in stream control. Laboratory experiments using a 24 hour discharge schedule with a 2 to 5 day retention period between discharge appears to offer some promise of success.

CHEMISTRY

Facets of BOD and laboratory estimates of actual stream BOD received consideration as usual. Chase and Ferullo (48) found water-logged leaves to exert a substantial drain on stream oxygen resources under aerobic conditions, and the long time BOD of maple leaves was reported to be 75% of dry weight; while for oak leaves and pine needles, the corresponding figure was approximately 50%. Gaffney and Heukelekian (88) reported exhaustive studies of the BOD of the lower fatty acids in this journal. Oberton and Stack (161) catalogued factors of importance in making significant laboratory measurement of the BOD of industrial wastes. Ettinger (74) attempted to generalize on factors common to biological oxidations.

Resnick and others (188) reported they were unable to convert cyanate into cyanide by irradiation or by addition to anaerobic substrates.

Bunch and Barth (36) presented studies of the possible use of immunological procedures for the detection of fermentation wastes. Using antisera prepared against Penicillium chrysogenum, Streptomyces lavendulae, it was shown that microgram amounts of metabolites from these organisms could be added to river water, recovered and detected.

OXYGEN SAG AND STREAM SELF-PURIFICATION

Recently published Proceedings of the Seminar on Oxygen Relationships in Streams held at the Robert A. Taft Sanitary Engineering Center, included a number of papers and new items of general interest. The several well-known approaches to selection of the necessary degree of waste treatment by analysis of oxygen relationships in the stream were ably presented and discussed. Dappert (65) discussed the applicability and use of stream data in the administration of a pollution abatement program with special attention to the use of "rule-of-thumb" techniques for the decision on waste treatment requirements. He emphasized the frequent need for decisions in the absence of adequate stream data and the importance of the use of judgment based upon knowledge of the local circumstances in each case. It was brought out in his paper and in the following discussions that in a major pollution abatement program involving many communities and industrial waste sources, the limitations of available personnel, funds, and time make it virtually impossible to accomplish exhaustive analysis in each case in terms of the oxygen sag theory. It was felt that, in view of these circumstances and the long-range objectives of the abatement program, considerable satisfactory progress had been made.

Streeter (204) provided the Seminar with a review of the general oxygen sag theory, bringing it up to date and indicating its usefulness today. Its limitations were pointed out, and Mr. Streeter discussed also some of the simplified approaches to the oxygen balance problems, and their limitations. O'Connor (163) presented a detailed review of the theory of atmospheric reaeration, together with the new approach to prediction of the reaeration velocity constant, k_2, based upon the theory of isotropic and non-isotropic

turbulent flow. One area of some confusion still exists in this problem of determination of the rate of atmospheric reaeration, namely, that in field studies it is most difficult to separate out the effects of photosynthesis in stream reaches where algae occur in significant numbers. In effect, while reaeration rates may be measured under laboratory conditions, in the field what is really measured is a reoxygenation rate because of the effects of photosynthesis. Thus, the direct comparison of rate constants as determined in the field with rate constants computed on the basis of a theory of atmospheric reaeration remains somewhat in question.

The application of existing theories to the problem of estimating oxygen demands from river deposits of organic material was reviewed and discussed in detail by Velz (221). This paper contains an excellent review of the subject of sludge deposits and demands, together with practical examples illustrating the application of the theory earlier proposed by Streeter and illustration of some of the finer points of application.

Gameson (90) presented an excellent and detailed review of the results obtained by British workers in recent years, illustrating many of these results in the example of the Thames Estuary. This discussion included specific information and results on the solubility of oxygen in sea water, the relation between the BOD and the UOD (Ultimate Oxygen Demand), tidal mixing, and the exchange coefficient for reaeration. Considerable information was presented regarding factors that affect the reaeration exchange coefficient, as well as a method for direct measurement of the exchange coefficient in the field. Thomas (216) presented a discussion of the mixing and diffusion of wastes in streams. Definitions and equations describing the processes involved were presented, with emphasis on longitudinal

mixing. The effects of stream impoundments on the oxygen resources were discussed by Churchill (53). Detailed discussion of the hydraulics of reservoirs and the problem of thermal stratification was included, together with point-by-point indication of the effects on dissolved oxygen.

The problem of obtaining truly representative samples and satisfactory data from field studies was discussed by Haney (107). It was emphasized that, before sampling is started, objectives of any survey should be clearly defined and sampling should be planned logically on the basis of these objectives. Some of the factors discussed in this paper included: the effects of river flow and the importance of obtaining samples under conditions of steady runoff; the location of sampling points relative to sources of pollution; the physical characteristics of the stream, including the location of power dams and impoundments; other conditions involving abnormalities of natural self-purification. Some discussion of the importance of adequate analytical procedures was also presented, as well as the need for continuous automatic sampling and recording equipment.

Schroepfer (195) discussed the application of stream survey data to waste treatment plant design, and illustrated a statistical approach with data applying to the Minneapolis-St. Paul situation. Thousands of analytical results were interpreted by statistical methods using the equation

$$DO_a - BOD_{ab} - BD_{ab} - DO_{tp} + R_{ab} = DO_b$$

for any stretch of river between the points A and B. DO_a and DO_b refer to the observed DO values at the upper and lower end of the stretch, BOD_{ab} refers to the amount of BOD exerted in the reach, BD_{ab} represents the oxygen demand of benthal deposits within the reach, DO_{tp} includes the effects on the oxygen resources of thermal pollution, and R_{ab} refers to the oxygen

income from reaeration and photosynthesis within the reach. The use of such an equation and approach proved especially valuable in the case illustrated, which involved a large capital investment for waste treatment facilities. Wisniewski (228) presented considerable information regarding the effects of algae on dissolved oxygen and BOD in the laboratory and in streams, and further information on this subject was presented during the following discussion.

A closing panel discussion of areas for future research was of considerable interest. Spies (203) indicated the need for fundamental studies of the development of slime growths in the presence of certain industrial wastes and their effects on the stream, as well as a need for investigation of the damaging effects of excessive turbidity in streams. He also indicated the need for information regarding the effectiveness of patented waste treatment processes, and the importance of developing continuous and automatic samplers. Pearson (176) indicated the need for fundamental studies of the role of turbulence and other physical factors in stream natural self-purification. He also discussed the importance of better methodology, especially with regard to the biological processes, and called for information leading to a quantitative description of the biota so that this information might be applied in engineering estimates. The growing importance of estuarine problems of pollution and the need for developing adequate approaches to this problem were also pointed out. A need for further study of the effects of thermal pollution was indicated by Schroepfer (196), who also called for studies leading to a reappraisal of the course of deoxygenation and the effects of temperature upon this process. Schroepfer also emphasized the desirability of a continuous DO

recorder. Kittrell (134) discussed the effects in streams of nitrification and indicated the need for further studies on this subject. He also indicated the importance, especially in small streams, of the absorption of BOD by biological slimes, and the possibility of storage of this organic material indefinitely by such slimes without attendant oxygen demands on the flowing stream. The occurrence of initially high BOD velocity constants was also indicated, together with the desirability of learning more about this phenomenon.

The ultimate oxygen demand (UOD) of sewage effluents and the course of oxidation are discussed in some detail in a recent paper by Gameson and Wheatland (92). The UOD has been computed on the basis of the organic carbon and nitrogen content of the sewage according to the following equation:

$$UOD = 2.67\ (\text{organic carbon}) + 4.57\ (\text{ammonia nitrogen} + \text{organic nitrogen}) + 1.14\ (\text{nitrous nitrogen})$$

This equation is believed by the authors to be quite general and may be used for estimates of the UOD in any case. Several examples are given and the course of the BOD reaction has been analyzed according to several possible mathematical hypotheses. Considerable discussion is presented of the possible bases for the above formula for UOD and for the hypotheses regarding the course of the BOD reaction. Truesdale and Vandyke (218) have reported on their studies of the effects of temperature on the rate of aeration of flowing water. In terms of the exchange coefficient, as developed by the British workers, a change of 1.5 percent per degree Centigrade is indicated as the average result. Some difficulties were encountered in this work and further work is reported to be in progress. Downing et al (71) have also indicated the effects of various pollutants on the rate of reaeration of

water. Measured in terms of the exchange coefficient, mixed household detergents reduced the rate of reaeration in clean water by amounts depending on the concentration of detergents. The effects of sewage effluents were similar to those of mixed household detergents but, in the absence of anionic surface-active agents, the effects of sewage effluents were considerably less.

Studies by Oldaker (166) of organic sludge deposits in the Connecticut River indicate the importance of recognizing the large oxygen demands that may result from the presence of such deposits. Moore (156) has reviewed the effects of discharge to streams of heated water (thermal pollution) in terms of the effects on oxygen resources and on the oxygen sag. Data are presented and parallel graphing of water and air temperatures of a small stream having no thermal pollution, an intermediate-sized stream having a high thermal load with resulting damaging effects, and a large river having a high heat input but good recovery. Results of a study to evaluate the aeration of streams at power turbines are presented by Scott et al (197). Data indicating the improvement in downstream DO conditions were collected in connection with the introduction of air by diffuser tubes and by venting turbines, and compared to base studies in which no air was introduced. The amount of oxygen absorbed by the water in passing through the turbines was dependent upon the influent water oxygen deficit and the rate of air admission. It was also determined that stream aeration by means of turbine venting yielded better results than aeration by the use of a compressor and air diffusion through tubes and plates.

A nomagraph facilitating exact solution for variables of the Streeter-Phelps oxygen sag equation has been prepared by Wastler and Wastler (223).

Using two resistance-capacitance circuits, Sinkoff et al (201) have developed an electrical analog computer for the oxygen sag curve which permits a wide variety of rapid computations involving the oxygen sag equation.

Churchill (54) has outlined the plans and course of present studies on the development of a mathematical formula for predicting the rate of reaeration in river reaches. Field studies are being carried out in reaches devoid of pollution. Reaeration rates thus determined are to be related to the physical characteristics of the reach on the basis of a dimensional analysis of the many parameters involved and the use of a statistical multiple regression technique. It is hoped to indicate the relative importance of the many physical factors and to develop a simplified dimensionally-consistent equation for practical application.

As a result of experiments with various organic compounds Bogan (30) indicates that the BOD and COD, while valuable measures of one form of stream pollution, are not adequate measures of all organic stream pollution. Neither test, it is stated, describes or identifies residual persistent organics that remain after partial biochemical oxidation. Intermediate products or by-products of biochemical degradation of oils and of alkyl benzene sulfonates are demonstrated in a series of experiments. The conclusion is drawn that oxidation may involve only a portion of the original molecule. The evidence also indicates that many consecutive enzyme reactions may be involved in the degradation of an organic chemical, these reactions taking place at rates which may be widely different. Certain of these enzyme reactions may regulate the total rate at which a substance can be oxidized. Other experiments involving oxidation rates of condensed phosphates in dilute solutions have been reported by Karl-Kroupa et al (128).

Beneden (25) has performed a number of experiments involving the question of whether BOD is actually a measure of the pollution load or of the bacterial activity. These experiments consider the effects of organic nitrogen concentration, seeding and dilution as well as the effects of additions of amino acids and large nitrogen molecules. Leclerc et al (144) have reported on their investigations of the Geer River in Belgium to determine self-purification capacity. The Geer was subject to seasonal pollution. Pöpel and Hunken (181) have developed a load distribution chart for permissible loads on rivers, minimum flow requirements, etc., on the basis of self-purification analysis. Pien (178) has described the application of natural self-purification principles in rivers polluted by milk trade waste waters.

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STREAM STUDIES AND SURVEYS

This year several papers have stressed the importance of collecting basic water quality data from the Nation's waterways. There is still an apparent lack of many fine survey studies reaching formal publication, thus preventing their review here. An extreme effort should be made to encourage publication.

Three significant papers by Palange and Megregian (171, 172) and Green (102) describe the cooperative USPHS water quality basic data program and its significance. Examples have been given of what water quality data developed on a nationwide basis can show. A program of this type should not be considered a monitoring or surveillance program; a better name for it would be "intelligence service". It should provide the means for continuous evaluation of the quality of water resources so that when any necessary corrective action is indicated, a warning or "alert" can be flashed. This warning should designate the general area needing relief and the degree of correction necessary. The basic data program is not intended to and should not take the place of detailed field surveys required for the solution of local problems.

The Federal network will provide data for interstate and international streams and for areas affected by Federal installations. These data will be issued annually in a government publication available to all. It is hoped that the States and other local agencies responsible for water resources will develop intrastate programs which can be linked with the national network, with the Federal stations used as reference points.

In addition to the principal benefits to be gained through the collection and publication of these fundamental data, the program has already

stimulated activities at many water plants. This activity has resulted in more comprehensive laboratory coverage and increased utilization of the newer parameters for assessment of water quality.

It is presently anticipated that the USPHS responsibility can be adequately covered by a maximum of 250-300 stations. When supplemented by intrastate programs, these should provide the data necessary for all future efforts aimed at the preservation and maximum utilization of the Nation's water resources.

Cleary (57) has published a paper stressing the value of collecting "vital data" and their value for water resources development programs. Cleary and Robertson (58) have described the modest beginning of the ORSANCO program, starting with 11 Ohio River Stations in 1951 and augmenting the network to include 43 locations today on the main stem as well as tributaries. A robot monitoring station project is discussed, considering the feasibility of adapting analytical instruments for continuous recording and automatic transmission of river quality data.

The Severn River Board (18) points out that no significant changes have occurred in any stream that is under their jurisdiction. Data indicate that rivers are holding their own as far as pollution is concerned, which is heartening in view of industrial expansion. Michalski (154) in discussing analyses for contaminates in water states that chemical, physical, and biological data are equally important in determining the extent of pollution of surface waters. Interpretation of results should be made by both limnologists and sanitary engineers, with support given by specialists in the fields of industry, agriculture, fish culture, public health, etc.

Beak (22) discusses the joint approach of chemical engineer and biologist in investigating industrial water pollution problems. Biological background of the BOD test and interpretation of results are outlined. Oxygen profiles, reaeration and self-purification are considered.

Field investigations of the Connecticut River by Oldaker (165) involved experiments that revealed the rate of accumulation of bottom deposits and their relationship to oxygen demands which may be exerted at various stations. Tsivoglou, et al (219) reported results of surveys on streams receiving radioactive wastes with long half lives from uranium ore refineries on the Colorado Plateau. Need for future research is stressed. The gross radioactivity and soluble radium content of waters downstream from mill effluents were found to be in excess of the usually accepted maximum permissible amounts. There was evidence of iridium and other radioactive elements in river muds and biological samples below mills. Swain and Newman (209) presented data from a hydrographical survey of the river Usk undertaken to determine the effect of cooling water from an electric power generating station on the condition of the river, specifically on salmon fisheries. They report that there has been no significant changes in the river. Salomonson (194) reports field studies of the drainage at Kyr Kebyns Bruk, Sweden to reveal the effects of spent sulfite of liquor. He reports that the polluting effect was not serious except in a strait between two lakes. On two occasions fish mortality occurred when weather conditions were particularly unfavorable for disposal of large volumes of waste liquor. The liquor in the future is to be evaporated and burned so no further pollution will occur.

An anonymous report (13) discusses the distribution and stratification of sulfite "dyes" in the Bleiloch Reservoir. Investigations revealed that pollution of the impounding reservoir is caused by waste waters from the Blankenstein sulfite cellulose factory. Water of the Saale flows through the reservoir in autumn and winter as a bottom stream in the old river bed, and in spring and summer, according to the thermal stratification, as a layer parallel to the surface at depths of 2-10 m. over the whole width of the reservoir. It mixes very slowly with water below and above and causes a rapid oxygen demand in the metalimnion and epilimnion; the hypolimnion is mainly unaffected. Even in a year of normal rainfall the self-purifying power of the reservoir is insufficient to deal with the pollution load and conditions deteriorated with the low rainfall at the end of 1953 and the beginning of 1954.

Gameson, Hall and Preddy (91) discuss the effects of heated discharges on the temperature of the Thames estuary. Their paper provides data for a rapid method of estimating the changes of temperature which would follow any alteration in the amount or position of discharged heat. Burt and Marriage (39) have investigated the Yaquina River estuary to determine the possible distribution of pollution from a proposed distribution of pollution from a proposed pulp mill. Salinity observations from the ocean to a point 20 miles upstream were made during low and high flow periods. Graphs show expected distribution for summer and winter conditions. The results of this study may be used as a guide for future pollution investigations in West Coast tidal estuaries which are similar to the Yaquina.

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sampling program is not carefully planned and the analyses accurately conducted, no matter how the data are manipulated graphically and mathematically, or how elegantly the report of findings is presented, the end result will be weak.

One of the milestones in the field of stream studies is Technical Report W58-2 (14) issued by the Public Health Service on a seminar, "Oxygen Relationships in Streams." This report contains the complete program of the seminar including the papers, formal discussions and informal discussion. The topics presented range from the use of stream data in field investigations, mixing and diffusion, reaeration, effects of impoundments, and sampling to the application of stream data to waste treatment plant design. Issued as a companion piece to this volume was a reprinting of the historic and classical document of Streeter and Phelps entitled "A Study of the Pollution and Natural Purification of the Ohio River," initially published in 1925, which has been out of print for many years (205).

STREAM STANDARDS

The perennial question of effluent versus stream standards was renewed by the Association of British Chemical Manufacturers through their technical executive officer. King (15) expressed the vital interest of the manufacturers in water conservation and in cooperation for pollution control. He pointed out that effluent standards are likely to be based on drought flows and may require rigidly excessive and costly treatment much of the time when stream flows are higher than minimum. Stream standards, on the other hand, allow flexible adjustment of waste discharges to varying stream discharges and permit optimum use of the natural purification capacities of streams. While fixed stream standards have not been adopted there is general acceptance, as guides, of: a maximum limit of 4 ppm of BOD; pH in the range of 6.0 to 9.0; suspended solids that will not cause silting of streams; and virtually complete removal of highly toxic substances such as cyanides and certain metal ions. The needs for more study and research on streams, wastes, and analytical methods, and for tailoring standards to the needs of the individual situation are emphasized.

The New England Water Pollution Control Commission, established by Compact, uses an extremely flexible set of stream standards. Knox (135) notes that this flexibility permits the individual states of the Compact group to retain their own standards and still to comply with the intent of the Commission standards. The Commission has adopted four classes of satisfactory water quality ranging from Class A, suitable for any water use, to Class D, suitable for transportation of sewage and industrial wastes without nuisance. Quantitative values are expressed for only two

constituents. DO shall not be less than 75 percent saturation for Classes A and B, and not less than 5 ppm for Class C. Class A sea waters for market shellfish shall not have a median coliform content in excess of 70 per 100 ml. Other standards are expressed in such terms as "none", "no appreciable amount", and "not objectionable".

Cherkinsky (49) proposes a theoretical basis for hygienic standardization of water courses receiving combinations of several harmful substances with similar noxious properties, such as smell, taste, and toxicity. The value of the MPC of each substance should be reduced by a factor equal to the number of similar substances in the wastes, and the sum of the concentrations of all such substances, expressed in percent of the MPC for each substance, should not exceed 100 percent.

EFFECTS ON WATER SUPPLIES

Metzler et al (153) report on the experiences at Chanute, Kansas, where from October 1956 to March 1957 the city was obliged to use treated sewage as its water supply because of an extreme and prolonged drought period. The deterioration in chemical quality was traced throughout the period. Bacteriological quality remained good.

Detergent pollution of ground water in Suffolk County, New York is discussed (79) in an area where individual wells and cesspools are installed on 60 ft x 100 ft lots. Regulations requiring larger lots for such installations have been adopted by the County Health Department (8).

Tastes and odors continue to be among the major effects of pollution on water supplies. Guinvarch (105) reports on experiences in France and notes the frequent occurrence of difficulties on weekends because of industrial discharges at those times. Carter (43) discusses problems in the London Metropolitan Supply. Ettinger and Rosen (75) review the work done at the Robert A. Taft Sanitary Engineering Center on trace organics in water, their odor characteristics, variations in response of odor panel members, etc. Campbell et al (42) studies the effect of certain chemicals in water on the flavor of brewed coffee. Taste thresholds were determined for ammonia, Calgon, chlorine, orthochlorophenol, porachlorophenol, disodium dihydrogen versenate, hydrogen sulfide, phenol, Tide, and trisodium phosphate.

ABATEMENT AND CONTROL

Reports from several sources during the year reflect the progress or lack of progress being made in the United States to abate pollution of our principal waters.

The Engineering News-Record (7), in reporting on "Where We Stand on Pollution Control," a resume of USPHS inventory on municipal sewage treatment facilities, points out the progress being made in this area. The population served by treatment plants increased 38 percent during the period 1953-57. This is compared with 8 percent for each of the previous 4-year periods following 1949. Furthermore, populations served by secondary or complete treatment increased 66 percent between 1949 and 1957. The disturbing note in the picture lies in the fact that in spite of the increase in volume of treatment plant construction, there has still been a slight increase in the pollution load from community systems discharging into the Nation's waters.

Ransom (185), in discussing "Progress and Cost Data in Ohio's Program for Water Pollution Control," has summarized the accomplishments in that State over the past 10 years and estimates that a total of 1/4 billion dollars, including projects now under construction, will have been put into new and rebuilt plants in that State.

Other indicators of progress come from Kansas (11) where the State Board of Health reports improved water quality in the Little Arkansas River due to better brine disposal practices. The most effective remedial measure appears to be the reintroduction of brines into underground formations.

Morgan (157) reports progress being made in reducing the mine acid load in Pennsylvania's streams. With the tremendous increase in strip

mining during the past 30-40 years, the major efforts of the control agency has been directed at control of these operations. Some of the recommended practices are:

1. Use of surface water diversion ditches to keep water out of strip mines.
2. Collect ground water and channel it by conduits through back-filled strip areas.
3. Don't strip across stream channels, thus leaving stream banks intact to protect natural channels in strip mine areas by hedge-hopping streams.
4. Control seepage from strip operations by leaving overburden undisturbed at the outcrop of the coal.
5. Backfill strip pits promptly to reduce the time sulfuritic material is exposed to air and moisture.
6. Prevent seepage into sulfuritic material by segregating gob or coal-bearing waste in backfill and sealing it off with impervious cover.

The spreading of the pumping from deep mines over longer periods than now used would even out the acid discharges to streams so that acid conditions would not exist in many areas. It is estimated that if pumping from deep mines were spread over 24 hours instead of much shorter periods there would be no acid conditions in the Ohio River below Pittsburgh.

A summary of the Oregon State Sanitary Authority's 1957 Progress Report (12) states that the stream pollution fight in that State is far from won. The Willamett River pollution was worse that year than during the previous three years due to low stream flow conditions.

Covill (64), in discussing water pollution problems in Great Britain, indicates their problems are not much different than those experienced in this country. He cites overloaded sewage treatment plants, inadequate operating personnel, insufficient removal of synthetic detergents, storm water discharges, increasingly diverse and complex array of industry effluents and increasing use of agricultural chemicals as constituting some of the principal problems in that area. He discussed each of these subjects in some detail.

The Chemical Industry Committee of ORSANCO (123) reports on the importance of considering waste disposal problems in the selecting of sites for chemical plants. The report emphasizes the desirability of supplying water poilution control agencies with available information regarding waste problems of proposed industries. Early cooperation between industry and regulatory agencies is essential for intelligent and wise planning.

The literature does not contain much on new water pollution control legislation during the past year. Some activity in this regard is indicated in other countries.

Descroix (70), in discussing "The Problem of Water in Germany," states that Germany has passed a new water law imposing controls on the use and discharge of waters. It provides effluent standards and completely outlaws certain discharges.

Kempf (130), in discussing proposed revisions to French stream pollution legislation points out that the new legislation is somewhat more realistic than that previously in existence which stemmed from an 1829 statute intended to prevent poaching and which provided for one to five years imprisonment for releasing anything injurious to fish in the streams.

The new law reduces the penalty but also provides for requiring industries to install treatment facilities where necessary.

As reported by Kyle (140), ten river purification boards are planned for Scotland. Duties of the Board include the promotion of water cleanliness and conservation of water resources. The Boards are authorized to make surveys, to engage and complete records of run-off, and they have a right to enter and inspect any plant or facility of water users. Notification of the industry and splitting of samples is required if the analytical data are to be admittable as evidence.

As progress in the construction of abatement works continues and as water uses expand more and more, attention is being given to monitoring water quality by regulatory agencies. This provides a check on the adequacy of treatment works and also supplies essential information on the effects of various pollutants on water quality.

Cleary (56) reports on the progress being made by ORSANCO in operating a network of 43 monitoring stations to provide a continuing record of information to aid in the diagnosis of stream conditions in the Ohio River. Personnel from public and private water works plants situated at various points on the Ohio River constitute the "Water Users Committee" of the Commission. Personnel from these plants collected samples at regular intervals for various analyses including the usual mineral analyses plus other special determinations such as coliform organisms, radioactivity determinations, and determination of organic compounds.

Palange and Megregian (172) also report on the activities of the Public Health Service in establishing a program for collecting basic data on water quality as directed under the Water Pollution Control Act.

During the first year under this operation 50 water sampling stations were established on the Great Lakes and Interstate streams of the United States. At each of these stations samples of raw water are collected and analyzed for radioactivity, plankton population, coliform organisms, and the conventional physical chemical analysis. This program also relies upon cooperation of various State and regulatory agencies, especially water treatment plant personnel located at sampling stations. The ultimate objective is to develop an integrated Federal-State-Local network giving adequate coverage to waters of the Nation.

Krause (136) discusses the Public Health Service study in the Arkansas and Red River Basins designed to define the sources of natural and artificial brine pollution and to formulate methods for making more of the waters in the area usable. High salinities in certain streams of these basins has long been a problem even before artificial pollution added its contribution. Preliminary investigations indicate that considerable improvement in the quality of some streams appears feasible. The study further points out the importance of basic water quality data in defining water quality needs and appropriate pollution preventive measures.

Hopkins and Neel (119) discuss the effects of impoundments on water quality in the Missouri River and point out that both beneficial and detrimental effects can result.

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